DECLARATION

I, Nobuo Arakawa, c/o Fukami Patent Office, Nakanoshima Central Tower, 22nd Floor, 2-7, Nakanoshima 2-chome, Kita-ku, Osaka-shi, Osaka, Japan, declare:

that I know well both the Japanese and English languages;

that to the best of my knowledge and belief the English translation attached hereto is a true and correct translation of Japanese Patent Application No. 2003-355955, filed on October 16, 2003;

that all statements made of my own knowledge are true;

that all statements made on information and belief are believed to be true; and

that the statements are made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 USC 1001.

Dated: October 3, 2008

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出願年月日
Date of Application: ２００３年１０月１６日

出願番号
Application Number: 特願２００３－３５５９５５

[ST. 10/C] : ［ＪＰ２００３－３５５９５５］

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２００４年　９月１３日

特許庁長官
Commissioner,
Japan Patent Office 小川洋

出証番号　出証特２００４－３０８２３２８

[Document Name]	Petition for Patent
[Reference Number]	1031576
[Filing Date]	October 16, 2003
[Destination]	To the Commissioner of the JPO
[International Class]	G02F 1/1339
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[Indication of Fee]	
[Deposit Account Number]	008693
[Fee]	21000
[List of the Accompanying Documents]	
[Document]	Scope of Claims for Patent 1
[Document]	Specification 1
[Document]	Drawings 1
[Document]	Abstract 1
[Number of General Power of Attorney]	0208500

[Document Name] Scope of Claims for Patent

[Claim 1]

A liquid crystal display panel comprising:

two substrates fixed together by a seal member with their main surfaces opposed to each other;

liquid crystal sealingly stored in a region surrounded by said two substrates and said seal member; and

a plurality of columnar spacers arranged in the region surrounded by said two substrates and said seal member, wherein

said column spacers are arranged such that a number density of said columnar spacers gradually decreases as the position moves from a center of a display region toward an outer periphery.

[Claim 2]

A liquid crystal display panel comprising:

two substrates fixed together by a seal member with their main surfaces opposed to each other;

liquid crystal sealingly stored in a region surrounded by said two substrates and said seal member; and

a plurality of columnar spacers arranged in the region surrounded by said two substrates and said seal member, wherein

a number density of said columnar spacers in a first region near an inner side of said seal member is smaller than that in a second region inside said first region.

[Claim 3]

A liquid crystal display panel comprising:

two substrates fixed together by a seal member with their main surfaces opposed to each other;

liquid crystal sealingly stored in a region surrounded by said two substrates and said seal member; and

a plurality of columnar spacers arranged in the region surrounded by said two substrates and said seal member, wherein

said columnar spacers include:

a first columnar spacer arranged in a first region near an inner side of said seal member, and

a second columnar spacer arranged in a second region located inside said first region and being higher than said first columnar spacer when receiving no load.

[Claim 4]

A method of manufacturing a liquid crystal display panel comprising:

a spacer forming step of forming columnar spacers on one or both of two substrates to be adhered together, said spacer forming step being configured to form said columnar spacers such that a number density of said columnar spacers decreases as the position moves from a center of a display region to be formed toward an outer periphery.

[Claim 5]

A method of manufacturing a liquid crystal display panel comprising:

a spacer forming step of forming columnar spacers on one or both of two substrates to be adhered together; and

a seal member arranging step of arranging a seal member on a main surface(s) of one or both of the substrates to be adhered together, wherein

said spacer forming step is configured to form said columnar spacers such that a number density of said columnar spacers in a first region near an inner side of said seal member is smaller than that in a second region inside said first region.

[Claim 6]

The method of manufacturing the liquid crystal display panel according to claim 4 or 5, further comprising:

a liquid crystal drop applying step of applying a drop of liquid crystal to one of said two substrates, wherein

said liquid crystal drop applying step applies a smaller quantity of liquid crystal than a calculated value obtained when said two substrates are parallel spaced from each other by a distance of a designed value.

[Claim 7]

A method of manufacturing a liquid crystal display panel comprising:

a spacer forming step of forming columnar spacers on one or both of two substrates to be adhered together; and

a seal member arranging step of arranging a seal member on a main surface(s) of one or both of the substrates to be adhered together, wherein

said spacer forming step includes a step of forming a first columnar spacer in a first region near an inner side of said seal member, and forming a second columnar spacer higher than said first columnar spacer in a second region inside said first region.

[Document Name] Specification

[Title of the Invention] Liquid Crystal Display Panel and Method of Manufacturing Liquid Crystal Display Panel

[Technical Field]

[0001]

The present invention relates to a liquid crystal display panel and a method of manufacturing the same, and particularly to a liquid crystal display panel including a columnar spacer as well as a method of manufacturing the same.

[Background Art]

[0002]

A liquid crystal display panel includes a substrate provided with drive elements for driving liquid crystal as well as a substrate provided with opposed electrodes opposed thereto, and these substrates are adhered together with their main surfaces opposed to each other with a space of several micrometers therebetween. A sealed space between the adhered two substrates is filled with liquid crystal.

[0003]

Fig. 11 is a schematic cross section of a liquid crystal display panel according to a prior art. For the sake of simplicity, Fig. 11 does not show drive elements, opposed electrodes and alignment films formed on main surfaces of substrates. Substrate 1a and 1b are adhered together via a seal member 2 with their main surfaces opposed to each other. A sealed space surrounded by two substrates 1a and 1b and seal member 2 is filled with liquid crystal 6. Columnar spacers 5 arranged in this space define a distance between substrates 1a and 1b.

[0004]

For manufacturing the liquid crystal display panel, the two substrates must be adhered together by the seal member with main surfaces thereof opposed to each other, and a region surrounded by the two substrates and the seal member must be filled with the liquid crystal.

[0005]

A vacuum filling method has been known as one of methods of filling a space with liquid crystal according to a prior art. In this method, two substrates are first adhered by a seal member together with their main surfaces opposed together while applying a pressure thereto. The seal member has an annular form, and is provided at a portion thereof with an opening. When a distance between the two substrates attains a predetermined value, the seal member is cured. Then, the substrates adhered together are cut into sizes of a predetermined display panel. The substrates thus cut are arranged inside a vacuum container, and a vacuum is produced in the vacuum container to produce a vacuum in the space between the substrates. After sufficiently exhausting a gas, the liquid crystal is brought into contact with the opening at the seal member, and the vacuum container is opened to an atmospheric pressure. The liquid crystal is supplied into the space between the substrates by the pressure difference between the pressure in the space between the substrates and the atmospheric pressure as well as the interfacial tension. After a predetermined quantity of liquid crystal is supplied, the opening at the seal member is sealed to store sealingly the liquid crystal. This method of sealingly storing the liquid crystal in the vacuum filling method suffers from a problem that the filling time increases with the size of the liquid crystal display panel.

[0006]

In recent years, therefore, a method called a "drop adhering method" has been performed for sealingly storing the liquid crystal (see, e.g., Japanese Patent Laying-Open No. 2001-281678). In the drop adhering method, drive elements, opposed electrodes and others are first formed on each of two substrates. Also, spacers for fixing a distance between the substrates are arranged on one of the substrates. Further, an annular seal member(s) for adhering the two substrates is arranged on one or both of the substrates. In this operation, the seal member is not provided with an opening, and is arranged in a closed annular form. Drops of a predetermined quantity of liquid crystal are put on one of the substrates. The two substrates are adhered together in a vacuum

with a high position accuracy, and then are exposed to the atmospheric pressure. Thereafter, the seal member is cured to store sealingly the liquid crystal between the two substrates.

[0007]

In the drop adhering method, the space surrounded by the two substrates and the seal member for filling it with the liquid crystal is closed by performing the adhesion. Since this adhesion is performed in a vacuum, air does not mix into the space filled with the liquid crystal, and only the liquid crystal is present therein. Therefore, by exposing the two substrates to the atmospheric pressure after adhering them in the vacuum, the two substrates are entirely and uniformly compressed together by the atmospheric pressure. The seal member is compressed and collapsed to a predetermined thickness.

[0008]

The spacers define the distance between the two substrates. The prior art has employed spherical plastic beads or the like as the spacers. In the structure employing the plastic beads, however, the liquid crystal material is not present in positions where the plastic beads are present, and the alignment does not occur in such positions so that leakage of back light, i.e., so-called "light leakage" occurs. In recent years, therefore, spacers of a columnar form (which will be referred to as "columnar spacers" in the invention) are formed as spacers on a substrate for adjusting a distance between the substrates (see, e.g., Japanese Patent Laying-Open No. 2003-131238). The columnar spacers are arranged in a region where interconnections are formed between picture elements, so that the light leakage can be prevented. Further, these spacers are resistant to collapse in the direction of thickness of the substrate, and can offer an advantage that irregularities do not occur in display even when a display screen of the liquid crystal display panel is pressed by a finger or the like.

[Patent Document 1] Japanese Patent Laying-Open No. 2001-281678 (pp. 3 - 6, Figs. 1 - 11)

[Patent Document 2] Japanese Patent Laying-Open No. 2003-131238 (pp. 3 - 5,

Figs. 2 - 8)

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0009]

The columnar spacers are more resistant to collapse in the height direction (i.e., the thickness direction of the substrate) than plastic beads and the like. The quantity of the applied liquid crystal can be readily controlled to apply a strictly accurate quantity of liquid crystal, but it is difficult in the formation of the columnar spacers to control accurately the size in the height direction, and variations occur in height of the columnar spacers. For example, variations of up to about ±0.2 μm may occur with respect to a designed value. Therefore, it is difficult to control the quantity of the applied liquid crystal in accordance with the height of the columnar spacers already formed, and this results in a problem of lowering the display quality.

[0010]

Fig. 12 illustrates disadvantages of a liquid crystal display panel according to a prior art. When columnar spacer 5 has a height lower than a designed value, the top surface of columnar spacer 5 is not in contact with substrate 1b as shown in Fig. 12(a) so that a distance between the substrates cannot be kept strictly constant. This results in a problem of lowering the display quality. Conversely, when the columnar spacer has a height larger than the designed value, the space surrounded by two substrates 1a and 1b as well as seal member 2 is not fully filled with liquid crystal 6 as shown in Fig. 12(b), and vacuum bubbles 28 occur to cause the problem of lowering the display quality. Even if vacuum bubbles 28 did not occur during the manufacturing of the liquid crystal display panel, the manufactured liquid crystal display panel may be used in an environment of a low temperature, in which case the liquid crystal condenses to produce the vacuum bubbles so that a similar problem occurs.

[0011]

In Japanese Patent Laying-Open No. 2001-281678, it is proposed to measure the

height of the columnar spacers and determine the drop quantity of liquid crystal based on the measured value. In this manufacturing method, the drop quantity of liquid crystal can be adjusted in accordance with the height of the columnar spacers, but it takes about 10 to 20 seconds for measuring the height of the columnar spacer in one position so that measurement of all the columnar spacers takes a very long time. Meanwhile, variations of about ±0.1 μm occur in height of the columnar spacers on the main surface of the substrate, and therefore, it is required to measure as many positions as possible. For measuring the heights of the many columnar spacers, a very long time is required, and the productivity lowers. If the heights of the columnar spacers are measured in fewer positions, the accuracy of the distance between the two substrates lowers.

[0012]

In particular, such a manner may be employed that a large number of medium or small cells each having a diagonal size from 1.5 inches to 4 inches are formed on a large substrate, and then may be cut off from each other. Thus, multiple patterning may be performed. In this case, the drop quantity of liquid crystal must be controlled for each cell. This requires measuring of heights of a great number of columnar spears, and thus requires a very long time.

[0013]

The invention has been made for overcoming the above problems, and an object of the invention is to provide a liquid crystal display panel that does not complicate adhering operations, and prevents lowering of the display quality as well as a method of manufacturing the same.

[Means for Solving the Problems]

[0014]

For achieving the above object, a liquid crystal display panel according to the invention includes two substrates fixed together by a seal member with their main surfaces opposed to each other; liquid crystal sealingly stored in a region surrounded by

the two substrates and the seal member; and a plurality of columnar spacers arranged in the region surrounded by the two substrates and the seal member. The column spacers are arranged such that a number density of the columnar spacers gradually decreases as the position moves from a center of a display region toward an outer periphery. Employment of this structure can provide the liquid crystal display panel that does not complicate the adhering operations, and prevents lowering of the display quality.

[0015]

For achieving the above object, a liquid crystal display panel according to the invention includes two substrates fixed together by a seal member with their main surfaces opposed to each other; liquid crystal sealingly stored in a region surrounded by the two substrates and the seal member; and a plurality of columnar spacers arranged in the region surrounded by the two substrates and the seal member. A number density of the columnar spacers in a first region near an inner side of the seal member is smaller than that in a second region inside the first region. Employment of this structure can provide the liquid crystal display panel that does not complicate the adhering operations, and prevents lowering of the display quality.

[0016]

For achieving the above object, a liquid crystal display panel according to the invention includes two substrates fixed together by a seal member with their main surfaces opposed to each other; liquid crystal sealingly stored in a region surrounded by the two substrates and the seal member; and a plurality of columnar spacers arranged in the region surrounded by the two substrates and the seal member. The columnar spacers include a first columnar spacer arranged in a first region near an inner side of the seal member, and a second columnar spacer arranged in a second region located inside the first region and being higher than the first columnar spacer when receiving no load. Employment of this structure can provide the liquid crystal display panel that does not complicate the adhering operations, and prevents lowering of the display quality.

[0017]

For achieving the above object, a method of manufacturing a liquid crystal display panel according to the invention includes a spacer forming step of forming columnar spacers on one or both of two substrates to be adhered together. The spacer forming step is configured to form the columnar spacers such that a number density of the columnar spacers decreases as the position moves from a center of a display region to be formed toward an outer periphery. By employing this method, it is possible to manufacture the liquid crystal display panel that does not complicate the adhering operations, and prevents lowering of the display quality.

[0018]

For achieving the above object, a method of manufacturing a liquid crystal display panel according to the invention includes a spacer forming step of forming columnar spacers on one or both of two substrates to be adhered together; and a seal member arranging step of arranging a seal member on a main surface(s) of one or both of the substrates to be adhered together. The spacer forming step is configured to form the columnar spacers such that a number density of the columnar spacers in a first region near an inner side of the seal member is smaller than that in a second region inside the first region. By employing this method, it is possible to manufacture the liquid crystal display panel that does not complicate the adhering operations, and prevents lowering of the display quality.

[0019]

Preferably, according to the invention, the method includes a liquid crystal drop applying step of applying a drop of liquid crystal to one of the two substrates. The liquid crystal drop applying step applies a smaller quantity of liquid crystal than a calculated value obtained when the two substrates are parallel spaced from each other by a distance of a designed value. Employment of this method can prevent lowering of the display quantity more reliably.

[0020]

For achieving the above object, a method of manufacturing a liquid crystal

display panel according to the invention includes a spacer forming step of forming columnar spacers on one or both of two substrates to be adhered together; and a seal member arranging step of arranging a seal member on a main surface(s) of one or both of the substrates to be adhered together. The spacer forming step includes a step of forming a first columnar spacer in a first region near an inner side of said seal member, and forming a second columnar spacer higher than said first columnar spacer in a second region inside said first region. By employing this method, it is possible to manufacture the liquid crystal display panel that does not complicate the adhering operations, and prevents lowering of the display quality.

[Effects of the Invention]

[0021]

The invention can provide the liquid crystal display panel that does not complicate the adhering operations and prevents lowering of the display quality, and can also provide the manufacturing method of the same.

[Best Modes for Carrying Out the Invention]

[0022]

(First Embodiment)

(Structure of Device)

Referring to Figs. 1 - 7, description will now be given on a liquid crystal display panel and a method of manufacturing the same of a first embodiment of the invention.

[0023]

Fig. 1 illustrates a first liquid crystal display panel of the embodiment. (a) and (b) are a schematic cross section and a schematic plan, respectively. As shown in Fig. 1(a), two substrates 1a and 1b are adhered and fixed together by a seal member 2. Substrate 1a is provided at its main surface with drive elements and others, and substrate 1b is provided at its main surface with opposed electrodes (not shown) and others. An inner space or region surrounded by two substrates 1a and 1b and seal member 2 is sealingly filled with liquid crystal 6. Substrates 1a and 1b are adhered and fixed

together with a space therebetween. Columnar spacers 5 determine the distance between the two substrates.

[0024]

Columnar spacers 5 are arranged in the region filled with the liquid crystal. Columnar spacer 5 has a circular cylindrical form, and has upper and lower surfaces in contact with the respective substrates. The first liquid crystal display panel of this embodiment includes a low-density region 32 serving as a first region near an inner side of seal member 2. It also includes a high-density region 31 serving as a second region inside low-density region 32. A number density of columnar spacers 5 in low-density region 32 is smaller than that of high-density region 31. Thus, the region surrounded by seal member 2 is formed of the two regions, and the number density of columnar spacers 5 in the inner region is higher than that in the outer region. Seal member 2 is arranged along the outer periphery of substrate 1b. For example, low-density region 32 in Fig. (1b) extends a width of 3 mm from seal member 2 toward a center of the display region. In high-density region 31, the distance between substrates 1a and 1b is substantially constant. Conversely, the distance between substrates 1a and 1b in low-density region 32 is substantially constant or gradually decreases as the position moves outward from the center of the display region.

[0025]

Fig. 2 illustrates a state of arrangement of columnar spacers 5. (a) is a plan of high-density region 31, and (b) is a plan of low-density region 32. Columnar spacers 5 are arranged in interconnection regions formed at boundaries between picture elements. The number density of columnar spacers 5 arranged in high-density region 31 is larger than the number density of columnar spacers 5 arranged in low-density region 32. In the liquid crystal display panel that includes the picture elements each having, e.g., a longitudinal size of 115 μm and a lateral size of 65 μm, columnar spacers 5 each having a diameter of 10 μm and a height of 4.5 μm are arranged in the high-density region at a rate of one columnar spacer for five picture elements. Conversely, in the low-density

region shown in Fig. 2(b), columnar spacers 5 having the same size and form as the above are arranged at a rate of one columnar spacer for 15 picture elements.

[0026]

The quantity of the liquid crystal sealingly stored in the embodiment is slightly smaller than a value which is calculated when the two substrates are parallel and spaced by a distance of a designed value from each other (and will be referred to as a "standard liquid crystal calculated value" hereinafter). In this embodiment, the quantity of the liquid crystal is equal to 96% of the standard liquid crystal calculated value.

[0027]

(Operation and Effect)

Fig. 3 is a cross section illustrating operations and effects of the first liquid crystal display panel of the embodiment. In the drop adhering method, the drop quantity of liquid crystal can be strictly adjusted, but it is difficult to provide the columnar spacers accurately having a designed height. Therefore, manufacturing errors are liable to occur in height of the columnar spacers. Fig. 3(a) is a cross section of a structure in which columnar spacers 5 accurately have a designed height. In this embodiment, the quantity of the stored liquid crystal is 96% of the standard liquid crystal calculated value, and thus is slightly smaller than it. Columnar spacer 5 is resistant to compression in the height direction, but can be slightly compressed. As shown in Fig. 3(a), therefore, the main surfaces of two substrates 1a and 1b are parallel to each other in high-density region 31 because columnar spacers 5 are arranged there at the high number density. In low-density region 32, since columnar spacers 5 are arranged at the low number density, the distance between two substrates 1a and 1b gradually decreases as the position moves from the center of the display region toward the outer periphery.

[0028]

When columnar spacer 5 has a height lower than the designed value, the distance between two substrates 1a and 1b is constant not only in high-density region 31 but also

in low-density region 32 as shown in Fig. 3(b). Since columnar spacers 5 have a small height, this structure reduces a space that is defined by columnar spacers 5 and is surrounded by substrates 1a and 1b and seal member 2. Consequently, the intended small quantity of stored liquid crystal substantially matches with the volume of the space surrounded by substrates 1a and 1b and seal member 2, and the main surfaces of two substrates 1a and 1b become parallel to each other even in low-density region 32.

[0029]

When formed columnar spacers 5 have the height larger than the designed value, the distance between substrates 1a and 1b decreases in low-density region 32 as the position moves outward from the center of the display region as shown in Fig. 3(c). Liquid crystal 6 filling the space surrounded by substrates 1a and 1b and seal member 2 decreases in quantity. In high-density region 31, the number density of columnar spacers 5 is higher than that in low-density region 32 so that the distance between substrates 1a and 1b becomes substantially constant in high-density region 31. Conversely, in low-density region 32 containing columnar spacers 5 at a low number density, the distance between substrates 1a and 1b gradually decreases as the position moves outward from the central portion of the display region (i.e., from high-density region 31 toward low-density region 32).

[0030]

As described above, the low-density region of the low number density is formed with respect to the high-density region located in the central portion of the display region so that the distance between the substrates decreases in the low-density region to prevent at least occurrence of vacuum bubbles even when variations are present in height of the columnar spacers, and therefore lowering of the display quality can be prevented. As is done in this embodiment, it is preferable that the sealingly stored liquid crystal is smaller in quantity than the standard liquid crystal calculated value determined when the two substrates are parallel spaced by a distance of the designed value. Employment of this structure can prevent lowering of the display quality in both

the cases where the height of the columnar spacer is higher than the designed value and where it is lower than the designed value.

[0031]

In this embodiment, the low-density region is formed near the inner side of the seal member. Thus, in the display region displaying pictures or the like, the low-density region extends from a peripheral portion thereof toward the outer side where the seal member is arranged. The invention is not restricted to this configuration, and may be configured such that the low-density region is formed in a central portion of the display region displaying pictures or the like, and the high-density region extends outward from the peripheral portion of the display region. However, in the case where a surface of a portion displaying pictures may be pressed by a finger or the like, irregularities may occur in the picture when the low-density region is locally pressed so that it is preferable to form the high-density region in a central portion of the display region and to form the low-density region in a peripheral portion of the display region. For example, when a user intends to touch a button on a display panel of a cellular phone, the user may make a mistake of pressing the display panel. Even in this case, the low-density region formed at the peripheral portion can prevent occurrence of irregularities in displayed pictures.

[0032]

Fig. 4 is a schematic plan of a second liquid crystal display panel of the embodiment. The liquid crystal display panel shown in Fig. 4 is of a type employing a CGS (Continuous Grain Silicon) liquid crystal in which a circuit operating TFTs for switching the liquid crystal and the like are formed on a glass substrate. The CGS liquid crystal is used in the display panel such as a digital still camera, a cellular phone or the like. In Fig. 4(a), a glass substrate 3 is provided at its main surface with a display region 35 including TFTs (Thin Film Transistors) and others, and is also provided at the main surface with a driver 10 for driving the TFTs. The liquid crystal is sealingly stored in a liquid crystal storing region 38 completely containing display region 35 and

driver 10. In a region provided with driver 10, there is formed a BM region 39 in which a black mask is formed on one of the substrates. In BM region 39, the mask conceals the inner side when viewed from the front side of the liquid crystal display panel.

[0033]

In Fig. 4(a), low-density region 32 is formed along the outer periphery of display region 35. In liquid crystal storing region 38, a high-density region is formed in a portion other than low-density region 32. More specifically, this portion is provided with columnar spacers arranged at a higher number density than low-density region 32. As described above, the invention can likewise be applied to the liquid crystal display panel of the CGS liquid crystal or the like.

[0034]

Fig. 4(b) shows a structure of the liquid crystal display panel of the CGS liquid crystal in which low-density region 32 is formed at a region avoiding display region 35. By employing this structure, whole display region 35 can be the high-density region. As described above, it is not essential that low-density region 32 contains a portion of the display region, and low-density region 32 can be formed in any position. For example, the low-density region may be formed only between the seal member and the display region.

[0035]

Fig. 5 illustrates a third liquid crystal display panel of the embodiment. In the above embodiment, the two regions, i.e., high- and low-density regions are formed, and the number density of the columnar spacers is constant in each region. In contrast to this, the third liquid crystal display panel is provided with columnar spacers 5 of which number density decreases as the position moves from the center of the display region toward the outer periphery as indicated by arrows 51. By this structure, the liquid crystal display panel can achieve effects similar to those of the first liquid crystal display panel in this embodiment. In this case, it is preferable that the quantity of stored liquid

crystal is slightly smaller than the standard liquid crystal calculated value. The liquid crystal display panel shown in Fig. 5 has the liquid crystal of a slightly small quantity as well as columnar spacers 5 formed accurately according to the designed values. In this liquid crystal display panel, the distance between substrates 1a and 1b gradually decreases as the position moves from the center of the display region toward the outer periphery.

[0036]

(Manufacturing Method)

Referring to Figs. 6 and 7, description will now be given on a method of manufacturing the liquid crystal display panel of this embodiment. The manufacturing method of this embodiment includes a spacer forming step of forming the columnar spacers on one or both of the two substrates to be adhered together, and a seal member arranging step of arranging the seal member(s) on the main surface(s) of one or both of the two substrates to be adhered together. The method also includes a liquid crystal drop applying step of applying drops of the liquid crystal onto one of the substrates, and particularly onto a region that will be located inside the annular seal member. The manufacturing method of this embodiment is a so-called drop adhering method in which two substrates are adhered together in a vacuum after the liquid crystal drop applying step. The manufacturing method of this embodiment will now be described primarily in connection with the method of manufacturing the first liquid crystal display panel.

[0037]

Fig. 6 is a schematic cross section showing adhesion of the two substrates. In the spacer forming step, columnar spacers 5 of a substantially uniform height are formed on substrate 1b by the photolithography method. Columnar spacers 5 are formed in a region where liquid crystal is to be sealingly stored. In a central portion of the display region, there is formed high-density region 31 including columnar spacers 5 at a high number density. In a portion outside high-density region 31 and near the inner side of annular seal member 2, there is formed low-density region 32 including columnar

spacers 5 at a lower number density than high-density region 31.

[0038]

Annular seal member 2 is arranged on the main surface of substrate 1a. Drops of liquid crystal 6 are applied onto a region of the main surface of substrate 1a surrounded by seal member 2. The drop quantity of liquid crystal 6 in this embodiment is slightly smaller than a designed value determined when the two substrates are parallel spaced from each other by a designed value.

[0039]

The two substrates are adhered together as indicated by an arrow 50 in Fig. 6. The adhesion is performed in a vacuum. After the combination, a surrounding space is opened to an atmospheric pressure so that the atmospheric pressure is applied to the whole surface of two substrates 1a and 1b, and thereby presses substrates 1a and 1b to each other.

[0040]

Fig. 7 is a schematic cross section showing, on an enlarged scale, the columnar spacer in the process of adhering two substrates 1a and 1b. Fig. 7(a) is the schematic enlarged cross section of the columnar spacer formed on the substrate. Columnar spacer 5 formed on the main surface of substrate 1b has a circular cylindrical form having a top surface of a diameter smaller than that of a bottom surface. Columnar spacers 5 are made of acrylic resin or the like. Columnar spacer 5 has such properties that it is more resistant to collapse than a plastic bead or the like. However, columnar spacer 5 has a margin for allowing compression by a compression width 40 shown in Fig. 7(a) when substrate 1a is adhered to substrate 1b as shown in Fig. 7(b). The height of columnar spacer 5 varies depending on the types such as a reflection-type liquid crystal display panel and a transparent-type liquid crystal display panel, but is substantially equal to several micrometers, and compression width 40 is equal to about 1/10 μm. As described above, columnar spacer 5 is compressed only slightly. However, columnar spacer 5 is compressed to an extent that can absorb a manufacturing error of columnar

spacer 5, and produces a portion where the distance between the two substrates decreases as shown in Fig. 3. In this manner, the manufacturing error in height of the columnar spacer is naturally absorbed, and the liquid crystal display panel preventing lowering of the display quality can be manufactured without complicating the adhesion operation.

[0041]

In this embodiment, the drop quantity of liquid crystal is equal to 96% of the standard liquid crystal calculated value. By applying the liquid crystal drops of the quantity smaller than the standard liquid crystal calculated value, it is possible to prevent occurrence of vacuum bubbles and irregularities on the display surface in either of the cases where the columnar spacer has the height of the designed value and where it has the height smaller or larger than the designed value, as shown in Fig. 3.

[0042]

For the second liquid crystal display panel of the embodiment, it is simply required to form, in each necessary region, the region including the columnar spacers at a small number density and the region including the columnar spacers at a large number density. By employing this method, it is possible to manufacture the second liquid crystal display panel of this embodiment. For the third liquid crystal display panel, the columnar spacers are formed such that the number density thereof gradually decreases as the position moves from the center of the display region to be formed toward the outer periphery.

[0043]

The columnar spacers can be formed by the known photolithography or the like. The columnar spacer of this embodiment has the circular cylindrical form. However, the columnar spacer is not restricted to this form, and may have, e.g., a quadrangular prism form. It is preferable that the number density of the columnar spacers, the material of the columnar spacer and/or the quantity of stored liquid crystal are appropriately changed according to the size and type of the liquid crystal display panel.

[0044]

(Second Embodiment)

(Structure of Device)

Referring to Figs. 8 and 10, description will now be given on a liquid crystal display panel of a second embodiment according to the invention as well as a method of manufacturing the liquid crystal display panel.

[0045]

Fig. 8 illustrates the liquid crystal display panel of this embodiment. (a) is a schematic cross section, and (b) is a schematic plan. Two substrates 1a and 1b are fixed together by seal member 2, and the space surrounded by two substrates 1a and 1b and seal member 2 is filled with liquid crystal, as is done in the liquid crystal display panel of the first embodiment.

[0046]

The liquid crystal display panel of this embodiment includes a low spacer arrangement region 34 as a first region near the inner side of seal member 2, and also includes a high-low spacer arrangement region 33 as a second region located inside low spacer arrangement region 34. The liquid crystal display panel includes first columnar spacers arranged in low spacer arrangement region 34 and high-low spacer arrangement region 33 as well as second columnar spacers arranged in high-low spacer arrangement region 33. In this embodiment, low columnar spacers 30 are formed as the first columnar spacers, and high columnar spacers 29 are formed as the second columnar spacers. High columnar spacer 29 is higher than low columnar spacer 30 when no load is applied thereto. In other words, when high columnar spacer 29 is released from a pressure applied by the two substrates, high columnar spacer 29 is higher than low columnar spacer 30.

[0047]

Fig. 9 illustrates arrangements of the columnar spacers in low and high-low spacer arrangement regions 34 and 33. Fig. 9(a) is a plan of high-low spacer

arrangement region 33. The two kinds of columnar spacers, i.e., high and low columnar spacers 29 and 30 are formed at interconnection regions in the boundary portions between the picture elements. High and low columnar spacers 29 and 30 are arranged in a mixed fashion. Fig. 9(b) is a plan of low spacer arrangement region 34. Only low columnar spacers 30 having a small height are formed in low spacer arrangement region 34. Between two substrates, there is sealingly stored the liquid crystal of the quantity required when the two substrates are adhered parallel to each other, i.e., the quantity of the standard liquid crystal calculated value.

[0048]

As described above, the liquid crystal display panel of the embodiment includes the two spacers having different heights when these are released from a pressure in the height direction. For example, in the liquid crystal display panel having the picture elements each having a longitudinal size of 115 μm and a lateral size of 65 μm, high columnar spacers 29 each having a diameter of 10 μm and a height of 4.5 μm are arranged at a rate of one spacer per ten picture elements. Further, low columnar spacers 30 each having a diameter of 10 μm and a height of 4.3 μm are arranged at a rate of one spacer per fifteen picture elements. In low spacer arrangement region 34, low columnar spacers 30 each having a diameter of 10 μm and a height of 4.3 μm are arranged at a rate of one spacer per fifteen picture elements. The designed distance between the two substrates is equal to the designed height of the low columnar spacer.

[0049]

Other structures are the same as those of the liquid crystal display panel of the first embodiment, and therefore description thereof is not repeated.

[0050]

In the liquid crystal display panel of the embodiment, since high columnar spacers 29 are arranged in high-low spacer arrangement region 33 at the higher number density than low columnar spacers 30 arranged in low spacer arrangement region 34, two substrates 1a and 1b in high-low spacer arrangement region 33 have the main

surfaces parallel to each other. Further, the distance between two substrates 1a and 1b in low spacer arrangement region 34 can be reduced with higher priority than that in high-low spacer arrangement region 33.

[0051]

When each columnar spacer has the height of the designed value, high columnar spacer 29 is compressed with higher priority than low columnar spacer 30, and the compression thereof stops when the height of high columnar spacer 29 becomes equal to that of low columnar spacer 30 (i.e., designed distance between the two substrates). As shown in Fig. 8(a), the two substrates become parallel.

[0052]

When the height of the columnar spacer is smaller than the designed value, high columnar spacers 29 in high-low spacer arrangement region 33 are not sufficiently compressed, and the distance between the substrates in high-low spacer arrangement region 33 becomes larger than the distance between the substrates in low spacer arrangement region 34.

[0053]

When the height of the columnar spacer is larger than the designed value, high columnar spacers 29 are compressed to the height equal to that of low columnar spacers 30, and the distance between substrates 1a and 1b decreases in low spacer arrangement region 34 so that occurrence of the vacuum bubbles can be prevented.

[0054]

As described above, the size of the space filled with the liquid crystal can be adjusted in both the high-low spacer arrangement region and the low spacer arrangement region. Therefore, the liquid crystal display panel of this embodiment can have a large margin for canceling a manufacturing error of the columnar spacers. In both the cases where the height of the formed columnar spacer is larger than the designed value and where it is smaller than the designed value, lowering of the display quality can be prevented without employing such a configuration that the quantity of the

stored liquid crystal cell is smaller than the standard liquid crystal calculated value.

[0055]

Other operations and effects are the same as those of the liquid crystal display panel of the first embodiment, and therefore description thereof is not repeated.

[0056]

(Manufacturing Method)

Referring to Fig. 10, description will now be given on the method of manufacturing the liquid crystal display panel of the embodiment.

[0057]

The columnar spacers are formed on substrate 1b by the photolithography method, and annular seal member 2 is formed on other substrate 1a. Then, the drops of liquid crystal 6 are put inside annular seal member 2. These manners are the same as those in the manufacturing method of the first embodiment.

[0058]

According to this embodiment, the spacer forming step of forming the columnar spacers on substrate 1b is configured such that low spacer arrangement region 34 is formed as the first region near the inner side of the seal member, and high-low spacer arrangement region 33 is formed as the second region inside low spacer arrangement region 34. Only low columnar spacers 30 serving as the first columnar spacers are formed in low spacer arrangement region 34. In high-low spacer arrangement region 33, low columnar spacers 30 as well as high columnar spacers 29 higher than low columnar spacers 30 are formed. Annular seal member 2 is arranged on substrate 1a, and liquid crystal 6 is arranged inside the region surrounded by seal member 2. Drops of liquid crystal 6 of the standard liquid crystal calculated value are applied.

[0059]

The adhesion of the two substrates is performed in a vacuum atmosphere. As indicated by an arrow 52, the main surfaces of substrates 1a and 1b are pressed after adhering the two substrates in the vacuum atmosphere. In this manner, the

compression is performed to locate the main surfaces of substrates 1a and 1b closer.

[0060]

In high-low spacer arrangement region 33, high columnar spacers 29 are formed in addition to low columnar spacers 30. For adhesion, high columnar spacers 29 come into contact with substrate 1a prior to low columnar spacers 30. By applying the pressure to the main surfaces of substrates 1a and 1b, high columnar spacers 29 are first compressed, and the compression will naturally stop when the quantity of liquid crystal 6 matches with the volume of the space surrounded by two substrates 1a and 1b.

[0061]

When the height of the formed columnar spacers is low, the compression stops during compression of the high columnar spacers so that the gap in high-low spacer arrangement region 33 becomes larger than that in low spacer arrangement region 34. Conversely, when the height of the formed columnar spacers is large, the distance between substrates 1a and 1b decreases in low spacer arrangement region 34. As described above, the adhesion of the two substrates can be performed depending on the manufacturing error of the columnar spacers while preventing occurrence of vacuum bubbles.

[0062]

Consequently, it is possible to manufacture the liquid crystal display panel that prevents lowering of the display quality due to occurrence of the vacuum bubbles and the like, similarly to the manufacturing method of the first embodiment. Further, it is possible to manufacture the liquid crystal display panel that prevents occurrence of irregularities in display even when the display unit is pressed by a finger or the like. Others are the same as those of the method of manufacturing the liquid crystal display panel of the first embodiment, and therefore description thereof is not repeated.

[0063]

In the figures relating to all the embodiments already described, the relative magnitudes of the heights of columnar spacers and the distances between the substrates

are exaggerated for ease of understanding. In the invention, there is a portion where the main surfaces of the two substrates are not parallel to each other, but this portion causes only a small change, and does not affect the display quality. The invention can be applied to both the monochrome liquid crystal display panel and the color liquid crystal display panel.

[0064]

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the scope of the present invention being interpreted by the terms of the appended claims.

[Brief Description of the Drawings]

[0065]

[Fig. 1] (a) and (b) illustrate a first liquid crystal display panel of a first embodiment.

[Fig. 2] (a) and (b) are plans illustrating arrangement of columnar spacers of the first embodiment.

[Fig. 3] (a) - (c) are illustrate operations and effects of the liquid crystal display panel of the first embodiment.

[Fig. 4] illustrates a second liquid crystal display panel of the first embodiment.

[Fig. 5] illustrates a third liquid crystal display panel of the first embodiment.

[Fig. 6] illustrates a method of manufacturing the liquid crystal display panel of the first embodiment.

[Fig. 7] (a) and (b) are schematic cross sections illustrating a manner compressing a columnar spacer.

[Fig. 8] (a) and (b) illustrate a liquid crystal display panel of a second embodiment.

[Fig. 9] (a) and (b) are plans illustrating an arrangement distribution of columnar spacers in the second embodiment.

[Fig. 10] illustrates a method of manufacturing the liquid crystal display panel in the second embodiment.

[Fig. 11] is a schematic cross section of a liquid crystal display panel according to a prior art.

[Fig. 12] is a schematic cross section illustrating disadvantages of the liquid crystal display panel according to the prior art.

[Description of the Reference Characters]

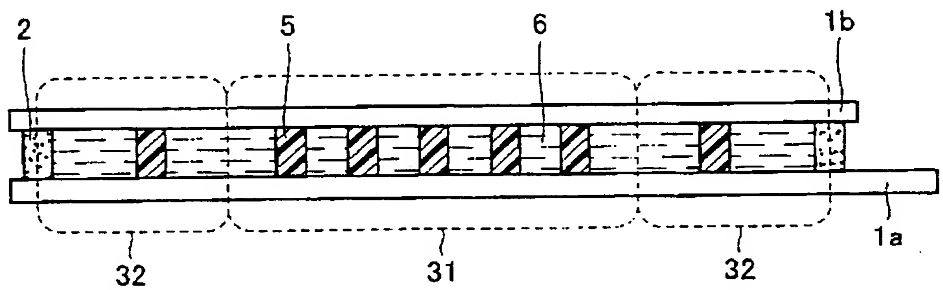
[0066]

1a and 1b: substrate, 3: glass substrate, 2: seal member, 5: columnar spacer, 6: liquid crystal, 7: picture element, 10: driver, 28: vacuum bubble, 29: high columnar spacer, 30: low columnar spacer, 31: high-density region, 32: low-density region, 33: high-low spacer arranged region, 34: low spacer arranged region, 35: display region, 38: liquid crystal storing region, 39: BM region, 40: compression width, 50, 51 and 52: arrows

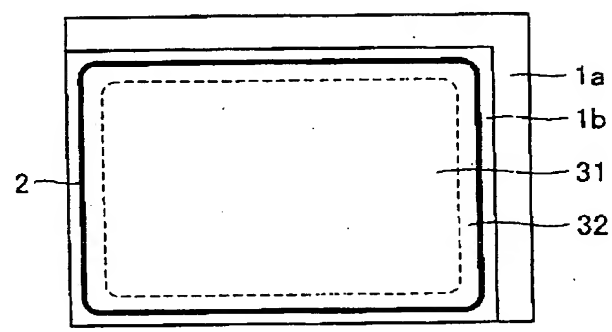
【書類名】　図面 [name of the document] drawing

【図１】Fig. 1

(a)

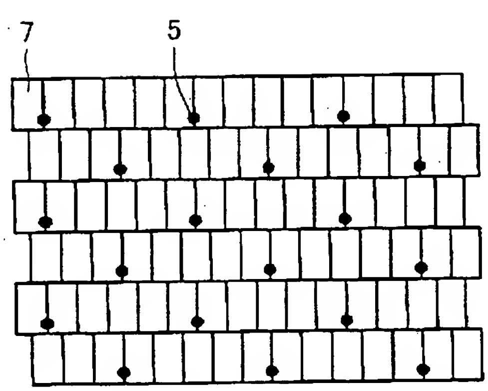


(b)



【図２】Fig. 2

(a)



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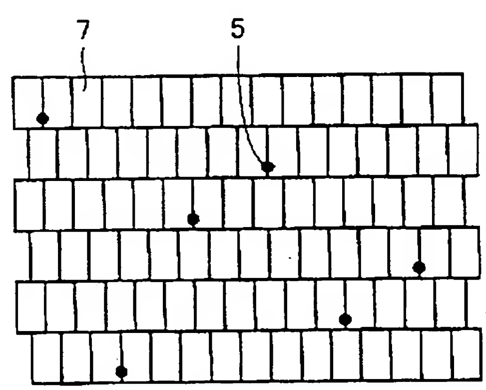
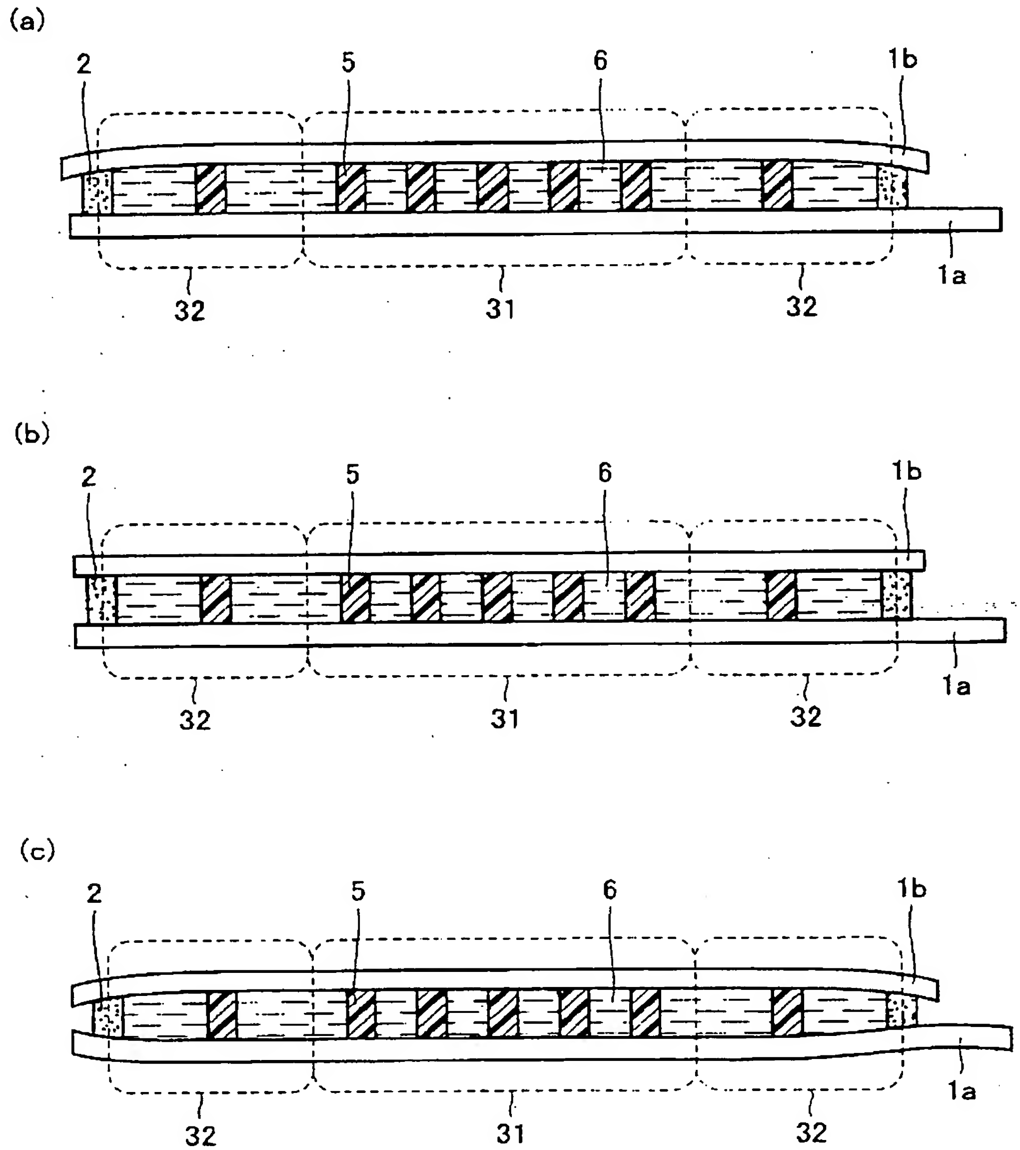
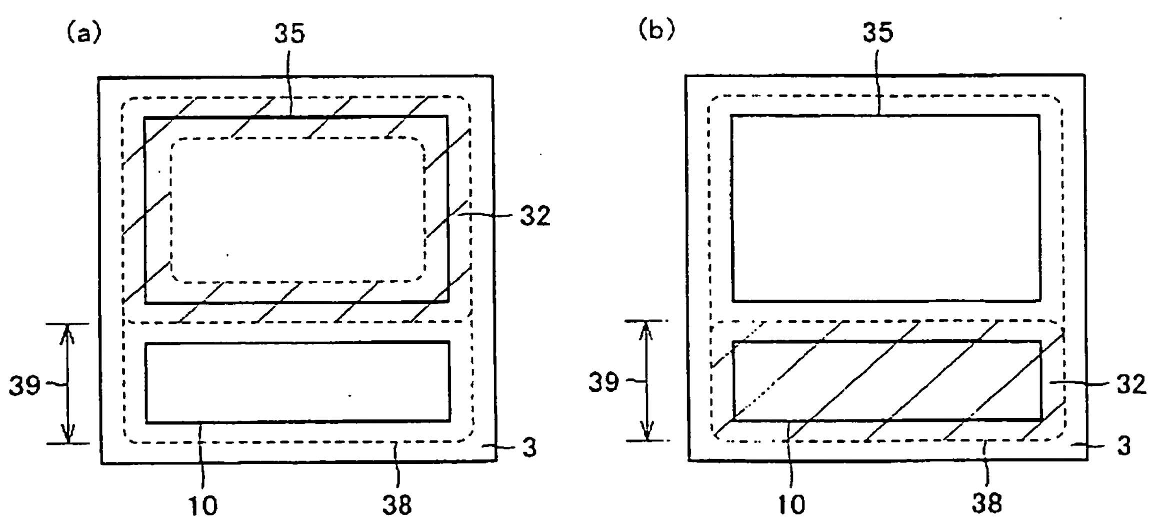


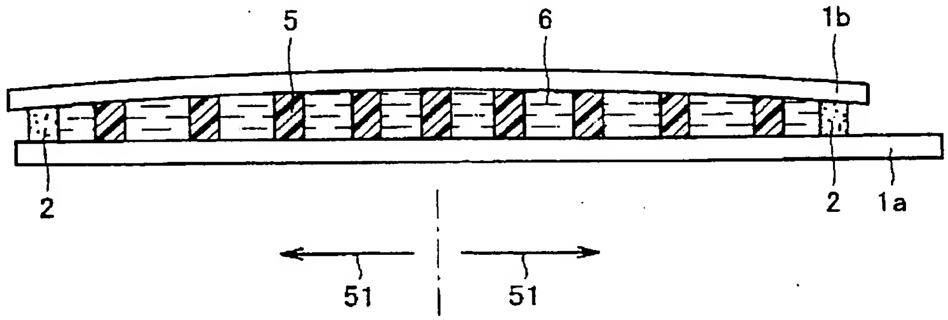
【図３】Fig. 3



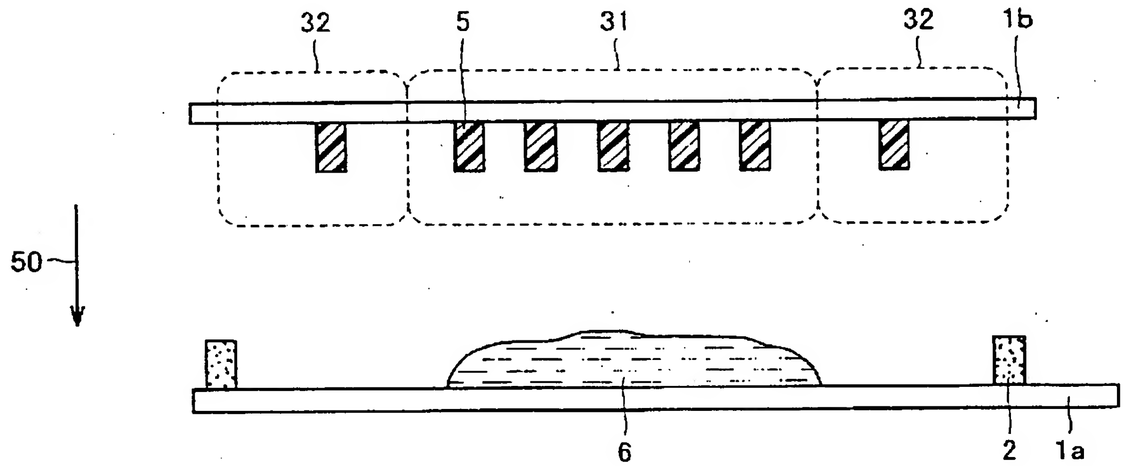
【図４】Fig. 4



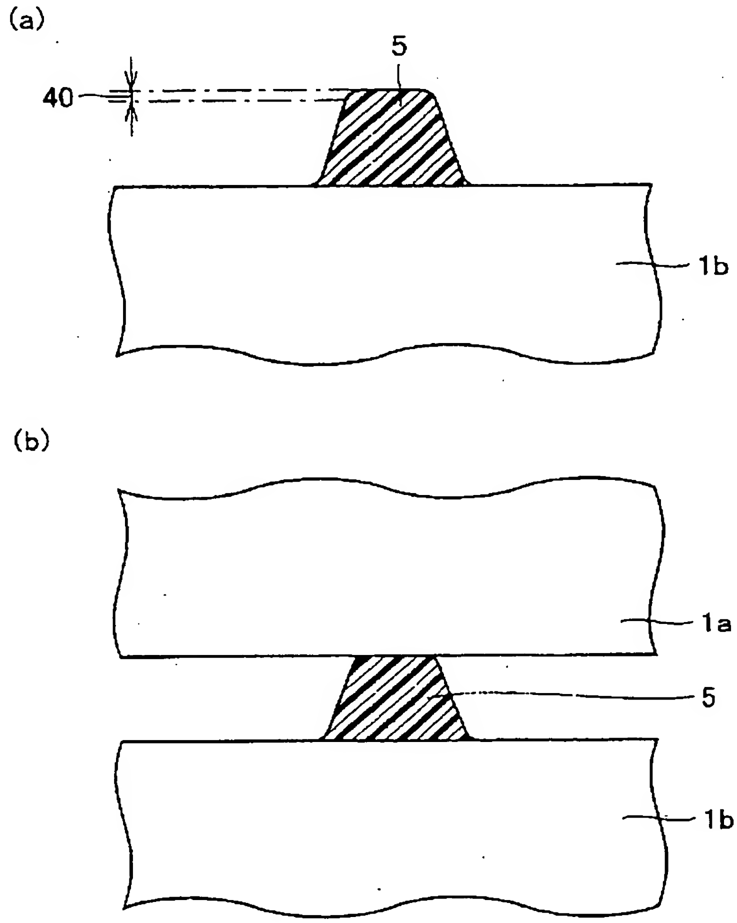
【図５】Fig. 5



【図６】Fig. 6

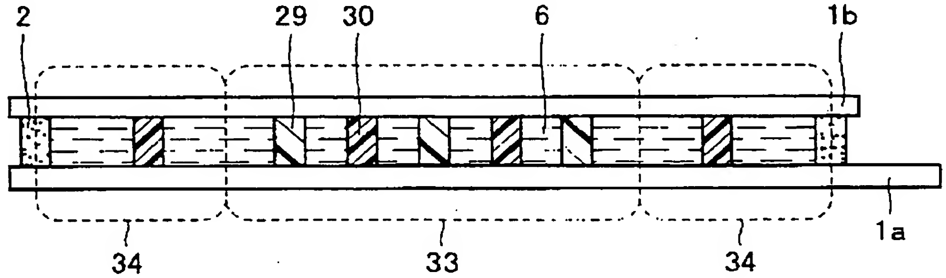


【図７】Fig. 7

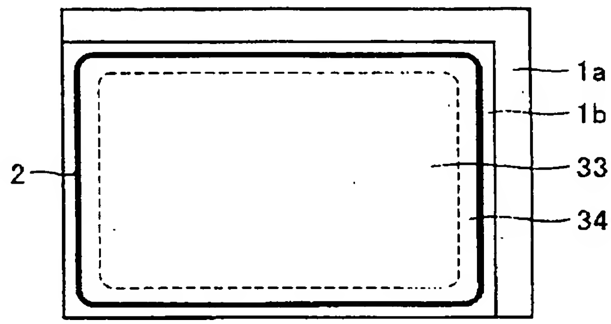


【図８】Fig. 8

(a)

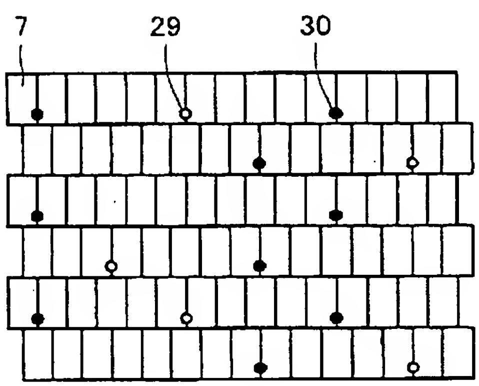


(b)

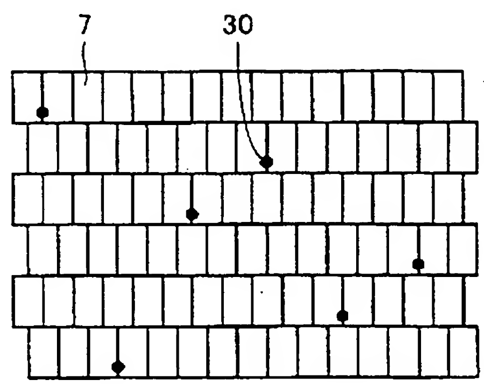


【図９】Fig. 9

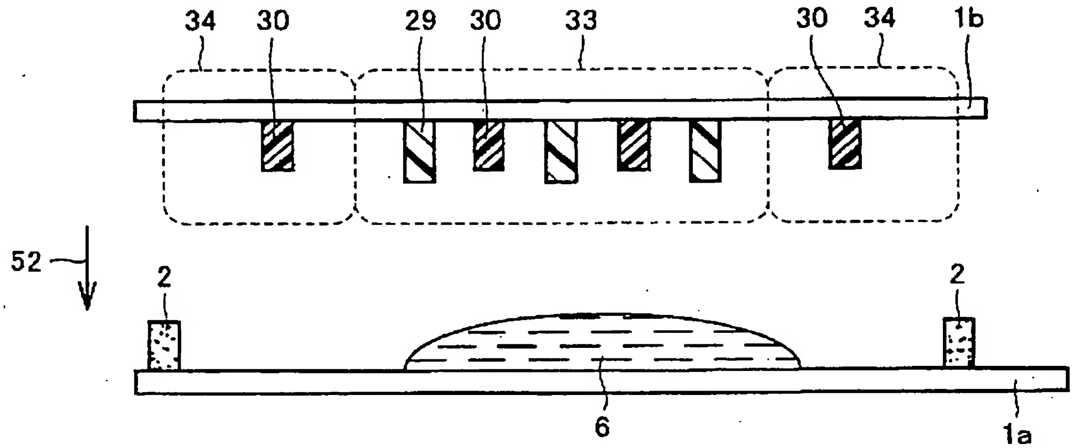
(a)



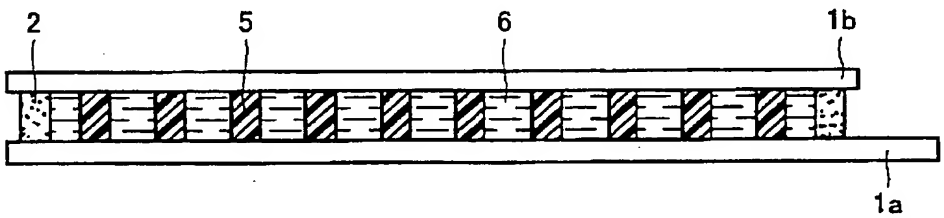
(b)



【図１０】Fig. 10

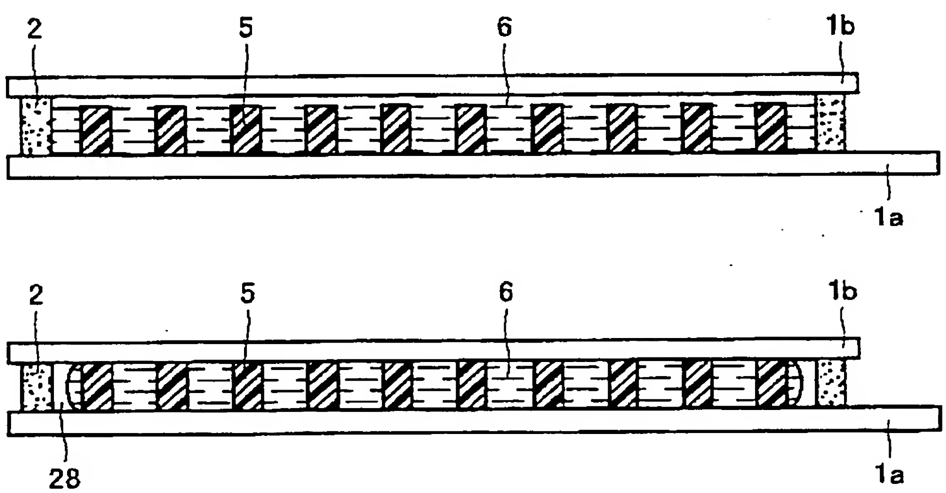


【図１１】Fig. 11



【図１２】Fig. 12

(a)



(b)

[Document Name] Abstract

[Abstract]

[Subject] An object is to provide a liquid crystal display panel and a manufacturing method thereof that do not complicate adhering operations, and prevent lowering of the display quality.

[Solving Means] A liquid crystal display panel includes two substrates 1a and 1b fixed together by a seal member2 with their main surfaces opposed to each other; liquid crystal 6 sealingly stored in a region surrounded by the two substrates 1a and 1b and the seal member 2; and a plurality of columnar spacers 5 arranged in the region surrounded by the substrates 1a and 1b and the seal member 2. A number density of the columnar spacers 2 in a low-density region 32 near an inner side of the seal member 2 is smaller than that in a high-density region 32 inside the low-density region 32.

[Selected Drawing] Fig. 1